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MEASURING SLEEP BY WRIST ACTIGRAPH

ANNUAL REPORT

Daniel F. Kripke, John B. Webster,

Daniel J. Mullaney, Sam Messin, and William Mason

March 1981

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A convenient method of monitoring personnel sleep and activity in field conditions is needed to promote medical planning for modern combat.

In the period from April 1980-March 1981, we have programmed, tested, and begun evaluations of a wearable digital activity system, and we have refined a computer process for recognizing sleep from this system. Together, these efforts enable us to collect data from freely ambulatory subjects which can be scored automatically for sleep/wake with accuracy comparable to EEG scoring. The system is ready for miniaturization leading to field use. ⌐ (cont. on back)

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20. Abstract, continued.

Our microprocessor-based digital activity monitor was built to our specifications, and we added external activity and illumination transducers. Actual data collection was implemented and 25 records totalling over 27,000 minutes have been obtained as of March, 1981. Fourteen records (12,739 minutes) collected with the digital monitor were scored retrospectively with 93.6% agreement with EEG sleep/wake scoring. Research is continuing to further increase the accuracy of the sleep recognition algorithm. Since the errors that occur include both mis-scoring sleep as wake and vice versa, they tend to cancel. Correlations between sleep durations scored from activity data and from EEG records were r=0.9760 for digital monitor data.

Current results now allow us to specify design criteria for a miniaturized wrist-mounted activity monitor suitable for field or combat use.

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SUMMARY

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FORWORD

For the protection of human subjects the investigator has adhered to policies of applicable Federal Law 45CFR46.

INTRODUCTION

Sleep loss and combat fatigue are increasing concerns for the modern army. A future war is likely to be extremely brief and intense, with victory and defeat determined in a few days or weeks. Soldiers using technically sophisticated modern weaponry will have little time for sleep, and plans must be made to enable personnel to perform effectively throughout the duration of a combat of unprecedented intensity. American troops may have to enter combat immediately after airlift to remote parts of the world, and plans must be developed to minimize the effects of jet-lag on personnel performance.

Military medicine therefore needs a practical method of quantifying sleep both to design personnel strategies and for potential monitoring of troops in actual field deployments.

Traditional physiologic methods for monitoring sleep through EEG-EOG-EMG recordings are completely impractical in actual or simulated combat settings, and subjective monitoring has been shown to be unreliable (1). In addition, both physiologic measures and observational methods for measuring sleep are costly, and considerable time is necessary to quantify sleep by scoring polygraph records.

We are developing a wrist activity monitoring technique as a solution to these problems.

Employing Delgado's (2) telemetric activity recording device, Kupfer et al (3) and Foster et al (4,5) described the use of activity data for quantifying sleep and assessing sleep quality in humans. Encouraged by the high correlations between EEG and actigraphic estimates of sleep -- 0.84 and 0.88 in two separate studies (6,7) -- Kripke et al (8) developed a system in which a piezoceramic activity transducer worn on a watchband recorded wrist activity onto a Medilog cassette tape recorder worn on a belt. With this transducer, Kripke et al (8) obtained a correlation of 0.98 between sleep duration determined from wrist activity and the EEG in five subjects.

A more exhaustive study of 63 nights of normal subjects and 39 nights in hospital patients with various sleep disorders was conducted under the first year of our contract (DAMD-17-78-C-8040, 1978-1979). All-night recordings of wrist activity, EEG, EMG and EOG were collected simultaneously on a 4-channel cassette. Each minute was scored as either sleep or wake by one rater using only activity data, and a second rater using only EEG-EOG-EMG data. The raters agreed on 94.5% of the minutes (96.3% for non-patients). Estimates of each subject's total sleep time with the two methods were correlated 0.89 (0.95 for non-patients). These results indicate that the wrist actigraphic analog recording contains sufficient information to produce a highly reliable scoring of sleep.

Having shown that sleep can be identified from activity data, we proposed in 1979 to design a 2-part sleep monitoring system. A digital activity monitor, consisting of an activity transducer, microprocessor and digital memory, would be worn on the wrist. A portable readout device, also microprocessor based, would read and reset the monitors, then interpret their data and generate a sleep report.

To realize this design, a first priority was to establish the optimal design, orientation and placement for the activity transducer. We found the piezo-ceramic transducer used in our previous research to be more sensitive than other available transducers and to be adequately omnidirectional. We also found the wrists to be more active than an ankle or the head, and therefore a better site for locating a transducer. The choice of wrists does not seem crucial, but the non-dominant wrist seems slightly superior (e.g., the left wrist).

Having established optimal transducer design characteristics, we turned our attention to digitizing, preprocessing and storing activity data. As reported in our 1979-1980 report, we found that digitizing at 240 Hz and summing every four digital conversions cancelled 60 Hz noise which sometimes contaminates activity recordings. We also found that a preprocessing algorithm which emphasized changes in activity level provided the best data for automatic sleep recognition. Our 1979-1980 report described our approach to empirically developing an algorithm to recognize sleep from digitized activity data. The further refinement of that approach, and its implementation in a wearable system will be described below.

FURTHER PROGRAM DEVELOPMENTS

Method

Data were obtained from subjects participating in studies involving EEG recording during both wake and sleep. A wrist activity transducer signal was sampled during both wake and sleep. The wrist activity transducer signal was sampled by the analog-to-digital (A/D) converter of our laboratory computer system at a conversion rate of 240 Hz. The analog data was digitized and stored as described in our 1979-1980 report, but only the optimal preprocessing transformation selected in that report was used in data analysis. A total of 20 records (13,488 minutes) were analyzed.

Development of the sleep recognition algorithm began with expressions incorporation a weighted sum of combinations of the digital data with potential for discriminating sleep from wake. Specifically, the expression took the form:

$$D = S \times (W_1 T_1 + W_2 T_2 + W_3 T_3 + W_4 T_4 + W_5 T_5 + W_6 T_6)$$

where S was a scale factor, W's were weights, and:

$T_1 =$ the sum of the digital activity values for all 30 2-second data epochs in a minute,

$T_2 =$ the activity value for the single most active epoch,

$T_3 =$ the sum of the activity values in the two most active epochs separated by at least 30 seconds,

$T_4 =$ the sum of the activity values in the most active 8 epochs.

Terms T_5 and T_6 were themselves weighted sums of term T_1 over the preceding 4 and following 2 minutes:

$$T_5 = W_{51} T_{1,i-1} + W_{52}T_{1,i-2} + W_{53}T_{1,i-3} + W_{54}T_{1,i-4}$$

$$T_6 = W_{61}T_{1,i+1} + W_{62}T_{1,i+2}$$

where $T_{1,i-1}$ is the maximal epoch value for the preceding minute, $T_{1,i+1}$ for the following minute, etc.

A minute was scored 'wake' if $D \geq 1.0$. For each given combination of weights, a range of weights (W) and scale factors (S) was substituted into the above expression for each minute, and the resulting sleep/wake score for all minutes. The proportion of minutes for which the automatic score and EEG score agreed was then computed for each scale value, and the maximum agreement served as a retrospective measure of the effectiveness of the weighting. The computer program (Appendix 1) varied the weighting of one term at a time, and searched for the combination of weights which produced the highest agreement.

As preliminary results became available, it became apparent that better agreement was obtained when $W_1 = W_3 = W_4 = 0$, i.e., the maximal epoch value in each minute was the best discriminator of sleep and wake. This unexpected result was extremely fortunate, since it permitted reducing the data required for sleep scoring by an order of magnitude compared to our prior expectation. We had expected that all 2-second epoch values for each minute would have to be stored.

Accordingly, a second expression was developed:

$$D = S \times (W_1 T_{2,i-4} + W_2 T_{2,i-3} + W_3 T_{2,i-2} + W_4 T_{2,i-1} + W_5 T_{2,i} + W_6 T_{2,i+1} + W_7 T_{2,i+2})$$

where W's represent weights and $T_{2,i}$ represents the maximal epoch value (T_2 in the previous expression) for the current minute, $T_{2,i-1}$ for the previous minute, $T_{2,i+1}$ for the succeeding minute, etc. Again, the computer varied the weighting and compared the resulting sleep/wake score with the EEG score until maximal agreement was obtained.

Seventeen of the 20 records were used in the algorithm development phase described above. The reamining three records were scored prospectively, i.e. each of the three records was scored individually with the single weighting and scale factor found optimal in the development phase. In this test, the laboratory computer simulated the actual deployment of an automatic sleep scoring system, with the results compared to EEG scoring.

Results

The optimal algorithm reached after analysis of the 17 records was:

$$D = .025 \times (.15T_{2,i-4} + .15T_{2,i-3} + .15_{2,i-2} + .08T_{2,i-1} + .21T_{2,i} + .12T_{2,i+1} + .13T_{2,i+2})$$

where $T_{2,i}$ represents the maximal epoch value in minute i, etc. If $D \geq 1.0$, the minute was scored 'wake', otherwise 'sleep'. The best retrospective agreement between sleep/wake scored automatically with this algorithm and scoring from

EEG records was 94.46% -- that is, 94.46% of all minutes from the 17 subjects were in agreement with the 'true' sleep/wake score. Agreement scores and the proportion of the record scored as sleep by EEG and by the automatic algorithm for each individual subject are shown in Table 1. Again, it should be noted that this is retrospective agreement, the data for these individuals already having been used to select the optimal algorithm.

The ability of this algorithm to score sleep/wake prospectively was tested with the remaining three records. For these records, only the single expression found optimal in the algorithm development phase was chosen prospectively to automatically score sleep/wake. Overall agreement of these three records with EEG scoring was 96.02%. Agreement and the proportion of each individual record scored sleep by both procedures is also shown in Table 1.

In order to understand the remaining shortcomings of the automatic sleep/ wake scoring algorithm, data for all minutes mis-scored were listed and compared with the paper record. In general, the conditional probability of mis-scoring wake as sleep was higher (.062) than mis-scoring sleep as wake (.039). A major reason for the higher probability of mis-scoring wake was the tendency of some subjects to lie in bed quietly for up to half an hour before falling asleep, while generating alpha-frequency EEG. On the other hand, while most examples of mis-scoring sleep were due to the presence of activity during sleep, the source of error in these cases was not so much a failure of the actigraphic scoring concept as a problem with the 1-minute scoring epoch chosen for this study. Many of the 'activity during sleep' errors actually represented arousals, but the EEG record showed that the period of wakefulness was less than the one-half minute required to score a 1-minute epoch as wake.

Since mis-scoring occurred in both directions, the estimates of total sleep duration were better than might be inferred from the minute-by-minute agreement figures. The correlation coefficient between the proportion of the record scored as sleep automatically from activity and as hand-scored from EEG were r=0.9889 (for the 17 records scored retrospectively) and r=0.9982 (for the 3 prospective records). Thus, the automatic scoring represents the relative duration of sleep extremely accurately. Since sleep duration is the dimension of sleep most crucial to sustaining performance, we feel that the automatic sleep recognition procedure described here represents a very effective scoring technique.

A further test conducted with these data sought to determine the resolution in the stored data necessary to achieve these levels of accuracy. The digital activity value was stored on disk as a 16-bit word, i.e. a number in the range of 0-32767. To investigate the resolution requirement, the sleep recognition program was repeated with the same data, but the resolution was reduced by dividing by powers of 2 and truncating. There was no decrease in agreement with 4-bit data (0-15) and a decrease of only 0.1% with 3-bit data (0-7). This surprising result is important, since it means that more data can be stored in a given memory capacity of the wearable activity monitor, providing appropriate scale factors are chosen.

TESTING THE DIGITAL ACTIVITY MONITOR

In our original proposal to produce a wearable digital activity monitor, we suggested a design in which the signal from a piezo-ceramic activity transducer would be entered through an analog-to-digital converter into an IM6100 microprocessor, and the processed activity values stored in random-access memory. All electronic components of this proposed system would be CMOS for minimal power consumption.

As noted in our 1979-1980 Annual Report, we found that these components could be assembled by the Vitalog Corporation*. After extensive discussions with Vitalog, we ordered a prototype monitor consisting of an IM6100 microprocessor, IM6001 Parallel Interface Element, 6K x 12 RAM memory, 512 word EPROM memory, 8-channel A/D converter, crystal clock and an LED indicator light. The unit is powered by rechargeable 5.6 volt batteries. It is enclosed in a 15 cm x 9 cm x 5½ cm plastic case. Vitalog also provided an interface between the monitor and our Apple microcomputer.

After receiving the monitor, we designed and built an external transducer incorporating a piezo-ceramic element, a photocell, a battery and amplification circuitry necessary to match the A/D input requirements. (The photocell was included to permit an objective measure of "lights out" and "lights on" and potentially to investigate sleep onset latency.) This external transducer, 7 cm x 4 cm x 2 cm, is worn on a wrist band like a watch. It is attached to the monitor by a cable. A schematic diagram of the transducer circuitry is presented as Figure 1.

Having assembled and tested the monitor system, we began by investigating its technical capabilities. One very important technical consideration was the useful life of the battery charge, since this limits the duration of a recording session. Battery drain was found to be 3.4 mA when the processor was halted and 8.5 mA when running. Since in most applications the processor is idling much of the time, a third state (WAIT) can be entered which keeps the processor running, but not executing instructions, at a drain of about 5.2 mA. The battery life was found to be 70 hours at 8.5 mA (running continuously) and 180 hours at 5.2 mA (running with WAIT). We subsequently devised a system for changing batteries without disturbing the recording, removing this limit to recording duration. We also investigated the accuracy of the crystal clock, and found that it lost 1.2 seconds each hour, well within acceptable limits. While considerable improvement in battery life can probably be obtained in any future model, the Vitalog system already demonstrates the feasibility of powering a microprocessor-based wrist activity monitor.

The majority of our effort in preparing the monitor system for use has been in development of a monitor program to direct the collection and storage of activity data. The algorithms for converting the continuous analog signal from the activity transducer to a value representing activity for each minute were equivalent to those discussed above. The monitor program that was ultimately developed, tested, and used to collect digital activity records digitized the signal from the transducer at 240 Hz, and 4 consecutive values were summed to provide a measure of activity free of 60 Hz noise. The sum was then transformed

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*Vitalog Corporation, 1056 California Avenue, Palo Alto, CA 94306.

to a difference score, and 120 such scores summed to produce an activity value for each 2-second data epoch. Every minute, the greatest 2-second activity value in that minute was stored. A voltage indicating the illumination level of the photocell was also digitized and stored each minute and a time code was signaled through the LED. The monitor program (Appendix 2) fills 548 memory locations, leaving 5696 locations available for data storage. This allows us to store two 12-bit data words (activity and illumination) each minute for 47 hours and 28 minutes. Since 4-bit resolution would be adequate, up to 6 times this duration or about 12 days sleep data could be stored were the illumination data sacrificed and battery changes feasible.

For test recordings, where it is necessary to compare digital activity records with EEG recordings, the LED was coupled through a receiving photocell to the polygraph to provide a time reference each minute on the paper record. The EEG recordings were scored, and both EEG and activity monitor scores were transferred to our laboratory computer system. To date, 25 laboratory recordings totalling over 27,000 minutes have been collected, and 14 have been fully analyzed retrospectively. Results are presented in Table 2. Retrospective agreement of these 14 records (12,739 minutes) is 93.6% with EEG scoring. The correlation coefficient between the proportion of each record scored as sleep by the two techniques is $r=.9760$.

In the final months of our 1980-1981 contract year, we plan to analyze a series of activity-monitored nights with prospective scoring to complete validation of our sleep scoring methodology. In addition, we will prepare a complete technical specification of the methodology from which a microminiaturized monitor wearable entirely on the wrist could be built. Our Vitalog digital monitor is fully programmable and in no way limited by the program described above. Any number of control programs could be written to record activity or illumination data differently and to monitor other functions through the unused A/D channels. These extended capabilities of the instrument can be utilized in our proposed 1981-1982 contract.

CONCLUSION

Mullaney, Kripke and Messin (9) have shown that a trained scorer can score wrist activity data for sleep/wake with accuracy approaching EEG scoring. In the present study, we have shown that wrist activity data can be digitized and scored automatically by computer with no loss in accuracy. Mullaney et al estimated that their activity scoring system was 5 to 10 times less costly than EEG scoring, and that the marginal decrease in accuracy was more than compensated by the greater amount of data that could be collected for a given expense. We feel that the automatic scoring system described here further improves the cost-benefit relationship by replacing the largely mechanical analog recording and playback system, including the polygraph, with an all-digital system. Automatic scoring is accomplished in seconds, eliminating the hours of skilled labor needed for writing out a polygraph record and the many minutes needed for visually scoring the record. Elimination of a scorer further reduces costs and for the first time makes the identification of sleep and wake fully objective, without the many opportunities for error and variability presented by human scoring. We are continuing with further algorithm refinements and testing, but it is unlikely much improvement can be obtained over the current results, nor is much improvement needed.

As of March, 1981, we have completed the major technical goals of our contract. Specifically, we have designed, built, tested, and evaluated a wearable digital activity monitor usable for sleep/wake scoring. Preliminary validation studies (using a retrospective technique) produced a r=.9760 correlation of automatic scoring of total sleep duration versus EEG scoring. This far exceeds our 90% design specification. Our technical development has been extremely successful. Judging from our experience with the same algorithm utilized with the laboratory computer, we believe there will be little or no degradation of validity in prospectively scored records, nevertheless, we are completing prospective validation in the remaining months of our 1980-1981 contract. In addition, we will submit an exact technical specification giving hardware and software specifications for a miniaturized microprocessor-controlled activity monitor. With this specification, a miniaturized monitor wearable entirely on the wrist could be designed and produced with currently available technology.

A miniaturized wrist-mounted sleep monitor could be used in field trials or in actual combat to monitor the fatigue and sleep-loss of Army troops.

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Figure 1. Schematic diagram of external activity transducer, photocell and level-matching amplification circuitry
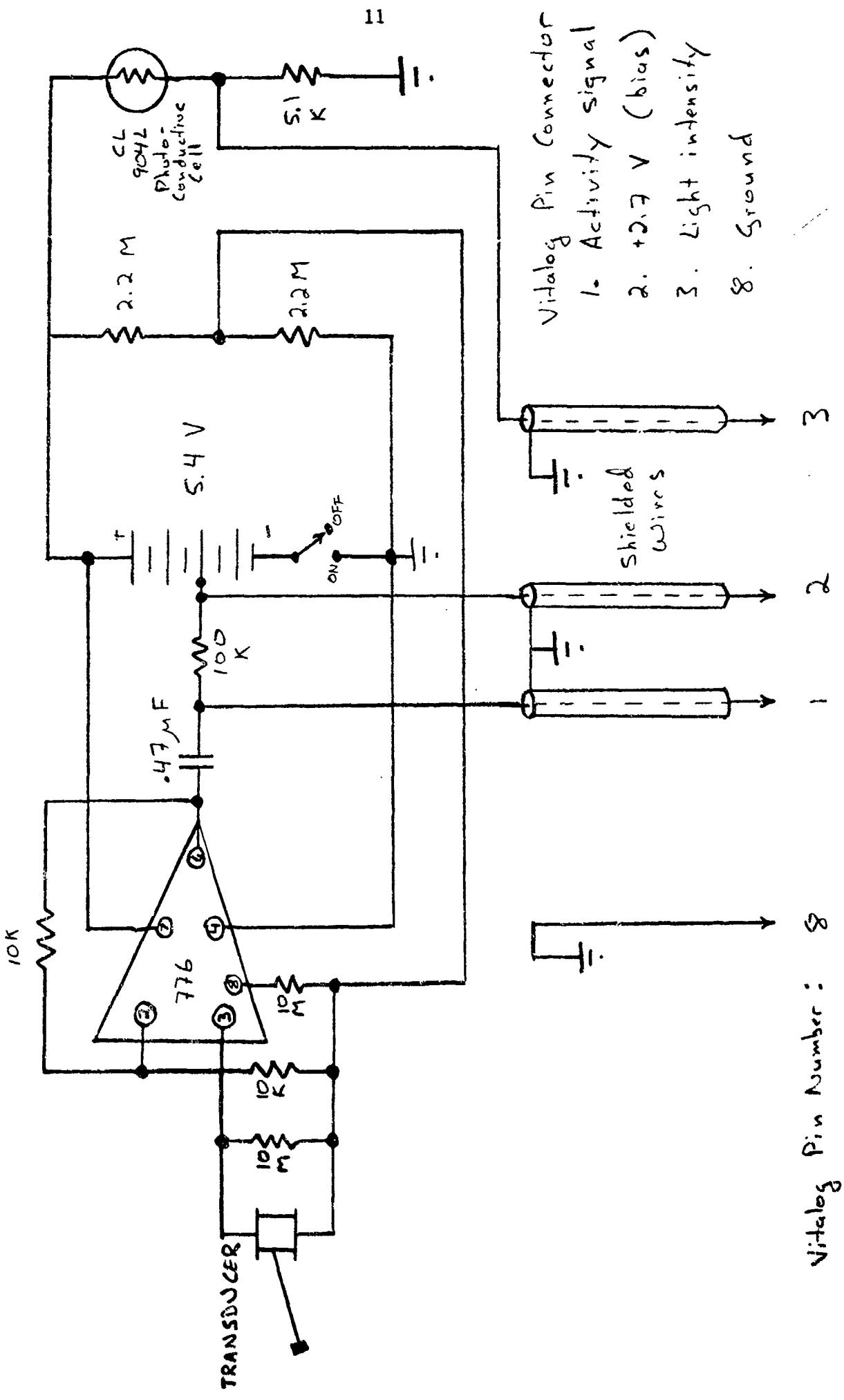
TABLE 1

Subject	Recording Duration (minutes)	% Agreement	% Sleep (EEG)	% Sleep (Act.)
1	353	97.17	0.00	2.83
2	574	96.17	45.47	46.86
3	632	95.89	56.80	59.65
4	903	83.82	29.57	34.33
5	660	97.42	54.55	56.21
6	798	95.36	41.73	44.11
7	845	96.80	37.99	40.95
8	1129	96.19	30.65	31.62
9	644	96.89	50.47	51.40
10	553	88.79	56.06	48.10
11	371	96.77	92.72	95.96
12	527	96.96	14.99	16.13
13	226	89.82	93.81	93.36
14	673	91.98	50.67	45.62
15	593	95.73	56.49	59.36
16	829	91.19	40.17	47.77
17	692	94.08	15.17	20.18
Total Retrospective	11002	94.46	42.09	43.98
18	369	93.50	70.19	76.69
19	846	93.62	28.84	31.68
20	1271	98.35	36.82	37.69
Total Prospective	2486	96.02	39.06	41.39

Table 1. Record duration, proportion of the record for which hand-scored EEG and automatically scored activity scores agree, and proportion of the record scored as sleep by the two techniques. Total duration and overall proportions for the records scored retrospectively and those scored prospectively are also presented.

TABLE 2

Subject	Recording Duration	% Agreement	% Sleep (EEG)	% Sleep (Act.)
1	366	89.92	85.71	95.80
2	2847	95.67	18.68	20.89
3	1472	97.95	24.27	25.91
4	2848	96.90	20.61	23.42
5	461	90.93	97.35	92.70
6	344	95.52	97.61	97.31
7	465	83.55	88.16	79.61
8	500	91.65	91.85	88.39
9	502	91.89	90.06	85.19
10	487	92.68	96.03	96.65
11	483	94.39	82.70	97.05
12	503	83.20	81.58	93.52
13	1100	92.12	35.47	39.32
14	487	90.17	89.33	98.33
Total Retrospective	12739	93.61	46.38	48.87

Table 2. Record duration, proportion of the record for which hand-scored EEG and automatically scored activity scores agree, and proportion of the record scored as sleep by the two techniques. Total duration and overall proportions are also presented.

APPENDIX 1

For Hewlett-Packard 1000

```
&WHEEL T=00004 IS ON CR00334 USING 00026 BLKS R=0000

0001         FTN4
0002   C        PROGRAM WHEEL(3,999)
0003   C        ..Finds parameters yielding best agreement for s/w.
0004   C     ------------------------------------------------------
0005   C
0006   C
0007   C        AUTHOR:  JOHN WEBSTER
0008   C
0009   C           VA Medical Center - San Diego
0010   C           Mail Code V-116
0011   C           La Jolla, California 92093
0012   C           Telephone: (714) 453-7500 X-3881
0013   C
0014   C        DATE OF CREATION:
0015   C           <<11:34 PM THU., 19 FEB., 1981>>
0016   C
0017   C        DATE OF CURRENT REVISION:
0018   C           <10:55 AM FRI., 6 MAR., 1981>
0019   C
0020   C        DATE OF LAST ACCESS:
0021   C           <10:55 AM FRI., 6 MAR., 1981>
0022   C
0023   C        FILE IDENTIFIER:
0024   C           &WHEEL
0025   C
0026   C        ABSTRACT:  Finds parameters yielding best agreement for s/w.
0027   C
0028   C        CALLING SEQUENCE:
0029   C           WHEEL,LUI,LUO,S/R)
0030   C
0031   C        PARAMETERS OR ARGUMENTS:
0032   C           LUI is interactive terminal, LUO is output device.
0033   C           S/R is single pass (0)/repeat (1) feature
0034   C           Default: Input=1 (System terminal)
0035   C                    Output=6 (Versatec)
0036   C                    S/R=0 (Single pass)
0037   C
0038   C        DETAILED DESCRIPTION:
0039   C     ------------------------------------------------------
0040           DIMENSION IDCB(3008),ISTAT(10),C(20),W(20)
0041           DIMENSION IPO(81,20,4),LU(5),IFILE(3),NW(5),CX(20)
0042           DIMENSION IBUF(3072),VECTR(20),PP(8),CW(20)
0043           DATA IFILE/2HHD,2HAT,2H00/
0044   C     ------------------------------------------------------
0045   C        ASSIGN I/O DEVICES
0046   C     ------------------------------------------------------
0047           CALL RMPAR (LU)
0048           IF (LU.EQ.0) LU=1
0049           LUI=LU
0050           IF (LU(2).EQ.0) LU(2)=6
0051           LUO=LU(2)
0052   C     ------------------------------------------------------
0053   C        INPUT PARAMETERS
0054   C     ------------------------------------------------------
0055   50      WRITE (LUI,100)
0056   100     FORMAT (/" 'HP' OR 'VI'?: _")
0057           READ (LUI,8099) NA
0058           IF (NA.NE.2HHP) GO TO 110
0059           IFILE=2HHD
0060           LO=16
0061           LIM=35
0062           MULT=1.
```

```
ØØ63          GO TO 15Ø
ØØ64      11Ø IF (NA.NE.2HVI) GO TO 5Ø
ØØ65          IFILE=2HVD
ØØ66          LO=66
ØØ67          LIM=65
ØØ68          WRITE (LUI,125)
ØØ69      125 FORMAT (" MULTIPLY VITALOG SCORE BY:_")
ØØ7Ø          READ (LUI,*) XMULT
ØØ71          LO=LO-XMULT*1Ø
ØØ72          LIM=LIM-XMULT*1Ø
ØØ73      15Ø WRITE (LUI,2ØØ)
ØØ74      2ØØ FORMAT (/" NUMBER OF MINUTES FORWARD: _")
ØØ75          READ (LUI,*) IFW
ØØ76          KJ=IFW+1
ØØ77          WRITE (LUI,25Ø)
ØØ78      25Ø FORMAT (" NUMBER OF MINUTES BACKWARD: _")
ØØ79          READ (LUI,*) IBW
ØØ8Ø          IW=IBW+IFW+1
ØØ81          IF (IW.LE.1Ø) GO TO 35Ø
ØØ82          WRITE (LUI,3ØØ)
ØØ83      3ØØ FORMAT (" *** 1Ø MINUTES MAX *** ")
ØØ84          GO TO 15Ø
ØØ85      35Ø WRITE (LUI,4ØØ)
ØØ86      4ØØ FORMAT (//" ENTER WEIGHTS FOR MINUTE. . ."/)
ØØ87          K=Ø
ØØ88          DO 5ØØ I=-IBW,IFW
ØØ89          K=K+1
ØØ9Ø          IF (I.GE.Ø) GO TO 4ØØ
ØØ91          WRITE (LUI,47Ø) K,I
ØØ92      47Ø FORMAT (3ØX,I2") I"I2": _")
ØØ93          GO TO 495
ØØ94      48Ø IF (I.GT.Ø) GO TO 49Ø
ØØ95          WRITE (LUI,481) K
ØØ96      481 FORMAT (3ØX,I2") *I*: _")
ØØ97          GO TO 495
ØØ98      49Ø WRITE (LUI,491) K,I
ØØ99      491 FORMAT (3ØX,I2") I+"I1": _")
Ø1ØØ      495 READ (LUI,*) W(K)
Ø1Ø1      5ØØ CONTINUE
Ø1Ø2      545 DO 55Ø I=1,4
Ø1Ø3          NW(I)=Ø
Ø1Ø4      55Ø CONTINUE
Ø1Ø5      56Ø WRITE (LUI,56Ø)
Ø1Ø6      56Ø FORMAT (/" ENTER UP TO 4 WEIGHTS TO BE 'BRACKETED' : _")
Ø1Ø7          READ (LUI,*) NW(1),NW(2),NW(3),NW(4)
Ø1Ø8          WRITE (LUI,//)
Ø1Ø9      58Ø FORMAT (//)
Ø11Ø      6ØØ LK=4
Ø111          IF (NW(4).EQ.Ø) LK=3
Ø112          IF (NW(3).EQ.Ø) LK=2
Ø113          IF (NW(2).EQ.Ø) LK=1
Ø114          IF (NW(1).EQ.Ø) LK=Ø
Ø115          LM=3**LK
Ø116          DO 76Ø I=1,IW
Ø117          CW(I)=W(I)
Ø118      76Ø CONTINUE
Ø119      775 DO 8ØØ K=1,61
Ø12Ø          DO 8ØØ J=1,2Ø
Ø121          DO 8ØØ I=1,4
Ø122          IPO(K,J,I)=Ø
Ø123      8ØØ CONTINUE
Ø124          IF (LU(3).EQ.1) GO TO 875
Ø125          IF (LUO.EQ.5) WRITE (LUO,85Ø)
```

```
0127  875  DO 4200 IQ=101,126
0128       IF (IIA.EQ.2HVI) GO TO 999
0129       IF (IQ.EQ.101) GO TO 4200
0130       IF (IQ.EQ.107) GO TO 4200
0131       IF (IQ.EQ.108) GO TO 4200
0132       IF (IQ.EQ.114) GO TO 4200
0133       IF (IQ.EQ.115) GO TO 4200
0134       IF (IQ.EQ.117) GO TO 4200
0135            GO TO 950
0136  900  IF (IQ.GE.115) GO TO 4200
0137  950  IFILE(3)=KCVT(IQ)
0138  C-----
0139  C  READ DATA FILE
0140  C-----
0141  1000  CALL OPEN (IDCB,IER,IFILE)
0142       IF (IER.LT.0) GO TO 9960
0143       CALL READF (IDCB,IER,IBUF)
0144       IF (IER.LT.0) GO TO 9910
0145       LEN=IBUF*256+IBUF(2)
0146       IL=LEN+2
0147       CALL READF (IDCB,IER,IBUF,IL,JL,-1)
0148       IF (IER.LT.0) GO TO 9920
0149       IF (LU(3).EQ.1) GO TO 2100
0150       WRITE (LUO,2000) IFILE,LEN
0151  2000  FORMAT (2H ,3A2,I8" MINUTES-")
0152  C-----
0153  C  PROCESS DATA
0154  C-----
0155  2100  DO 4000 I=3,IL
0156       DO 2200 J=IW,2,-1
0157       VECTR(J)=VECTR(J-1)
0158       ISTAT(J)=ISTAT(J-1)
0159  2200  CONTINUE
0160       ISTAT=1
0161       IF (IIA.EQ.2HVI) GO TO 2300
0162       IF (IBUF(I).LE.0) IBUF(I)=63
0163       IF (IBUF(I).LT.128) GO TO 2500
0164       IBUF(I)=IBUF(I)-128
0165       ISTAT=0
0166  2500  VECTR=FLOAT(IBUF(I))*XMULT
0167       IF (VECTR.GT.63) VECTR=63
0168       DO 3900 IZL=1,LN
0169       D=0.
0170       DOT=0.
0171       IF (I-2.LT.IW) GO TO 4000
0172       IF (NW(4).EQ.0) GO TO 3002
0173       CW(IRW(4))=W(NW(4))+((IZL-1)/27-1)
0174  3002  IF (NW(3).EQ.0) GO TO 3004
0175       CW(NW(3))=W(NW(3))+(MOD((IZL-1),27)/9-1)
0176  3004  IF (NW(2).EQ.0) GO TO 3006
0177       CW(NW(2))=W(NW(2))+(MOD((IZL-1),9)/3-1)
0178  3006  IF (NW(1).EQ.0) GO TO 3020
0179       CW(NW(1))=W(NW(1))+(MOD((IZL-1),3)-1)
0180  3020  VW=0
0181       DO 3040 IZ=1,IW
0182       VW=VW+CW(IZ)
0183  3040  CONTINUE
0184       DO 3050 IZ=1,IW
0185       C(IZ)=CW(IZ)/VW
0186  3050  CONTINUE
0187  C  (DOT PRODUCT LOOP)
0188  2600  DO 2700 K=1,IW
0189       DOT=DOT+VECTR(K)*C(K)
0190  2700  CONTINUE
```

```
0191        DO 3300 JJ=LO,LIM
0192        SCALE=JJ/1000.
0193        D=DOT*SCALE
0194        L=JJ-(LO-1)
0195        KS=0
0196        IF (D.GE.1.0) KS=2
0197        LS=ISTAT(KJ)
0198        KLS=KS+LS+1
0199        IPO(IZL,L,K-S)=IPO(IZL,L,KLS)+1
0200  3800  CONTINUE
0201  3900  CONTINUE
0202  4000  CONTINUE
0203  4200  CONTINUE
0204  4300  NS=IPO(1,1,1)+IPO(1,1,3)
0205        NN=IPO(1,1,1)+IPO(1,1,2)+IPO(1,1,3)+IPO(1,1,4)
0206        NNMAX=0
0207        DO 4700 J=1,LN
0208        NMAX=0
0209        DO 4600 I=LO,LIM
0210        L=I-(LO-1)
0211        NC=IPO(J,L,1)+IPO(J,L,4)
0212        NNMAX=MAXD(NNMAX,NC)
0213        IF (NNMAX.NE.NC) GO TO 4510
0214        SMAX=I/1000.
0215        MAXJ=J
0216  4510  NMAX=MAXD(NMAX,NC)
0217        IF (NMAX.NE.NC) GO TO 4650
0218        MAXC=NC
0219        SMAX=I/1000.
0220        MAXI=L
0221  4600  CONTINUE
0222        IF (NW(4).EQ.0) GO TO 4602
0223        CW(NW(4))=W(NW(4))+((J-1)/27-1)
0224  4602  IF (NW(3).EQ.0) GO TO 4604
0225        CW(NW(3))=W(NW(3))+(MOD((J-1),27)/9-1)
0226  4604  IF (NW(2).EQ.0) GO TO 4605
0227        CW(NW(2))=W(NW(2))+(MOD((J-1),9)/3-1)
0228        IF (NW(1).EQ.0) GO TO 4606
0229        CW(NW(1))=W(NW(1))+(MOD((J-1),3)-1)
0230  4606  VW=0
0231        DO 4650 I=1,10
0232        VW=VW+CW(I)
0233  4650  CONTINUE
0234        DO 4675 I=1,10
0235        CX(I)=CW(I)/VW
0236  4675  CONTINUE
0237        PC=100*FLOAT(NMAX)/FLOAT(NN)
0238        IF (LU(3).EC.1) GO TO 4700
0239        WRITE (LUO,4690) (CV(I),I=1,10),SMAX,PC
0240  4690  FORMAT (1H ,10F6.1,F7.4,F7.2)
0241  4700  CONTINUE
0242        PS=100*FLOAT(NS)/FLOAT(NN)
0243        PCC=100*FLOAT(NNMAX)/FLOAT(NN)
0244        DO 4850 LM=1,4
0245        PP(LM)=100*FLOAT(IPO(MAXJ,MAXI,LM))/FLOAT(NN)
0246  4850  CONTINUE
0247        IF (LU(3).EQ.1) GO TO 4950
0248        WRITE (LUO,4043)
0249  4043  FORMAT (//)
0250  4900  WRITE (LUO,4900) PCC,NN,PS,(PP(I),I=1,4)
0251  4900  FORMAT (//' PERCENT CORRECT: 'F6.2' %'/
0252       1/' MINUTES SCORED: 'I6
0253       2/' PERCENT ASLEEP: 'F6.2' %'/
```

```
0255 4950 IF (NW(4).EQ.0) GO TO 5002
0256       NW(4))=W(NW(4))+((MAXJ-1)/27)-1)
0257 5002 IF (NW(3).EQ.0) GO TO 5004
0258       NW(3))=W(NW(3))+(MOD((MAXJ-1),27)/9-1)
0259 5004 IF (NW(2).EQ.0) GO TO 5006
0260       NW(2))=W(NW(2))+(MOD((MAXJ-1),9)/3-1)
0261 5006 IF (NW(1).EQ.0) GO TO 5008
0262       NW(1))=W(NW(1))+(MOD((MAXJ-1),3)-1)
0263 5008 WRITE (LUO,5010) (W(I),I=1,18),SSMAX,PCC
0264 5010 FORMAT (1H ,18F6.1,FG.3,FG.2)
0265       IF (LU(3).EQ.0) GO TO 9050
0266       DO 9040 I=1,4
0267       NW(I)=NW(I)+1
0268       IF (NW(I).GT.IW) NW(I)=1
0269 9040 CONTINUE
0270       GO TO 600
0271 9050 WRITE (LUI,3609)
0272 0809 FORMAT (" MORE?: _")
0273       READ (LUI,8899) IANS
0274 0892 FORMAT (A2)
0275       IF (IANS.EQ.2HYE) GO TO 545
0276 9000 STOP 7777
0277 9003 WRITE (LUI,9990) IER
0278       STOP 1
0279 9910 WRITE (LUI,9990) IER
0280       STOP 2
0281 9920 WRITE (LUI,9998) IER
0282       STOP 3
0283 9990 FORMAT (" *** ERROR-I6" *** ")
0284 9999 STOP
0285       END
0286       ENDS
```

APPENDIX 2

For Vitalog IM6100 microprocessor

```
WORLD T-PROGRA IS ON CREATED USING CRORED BLKS R=0000

0001                          /ACTIGRPD
0002
0003
0004                          /RECORDS OUTPUT OF ACTIGRAPH (TRANSDUCER AND PHOTOCELL
0005                          /RESOLUTION=1 MINUTE, DURATION=47HR.28MIN
0006                          /TIME CODE EACH MINUTE THRU L.E.D.
0007
0008                          /AUTHOR: JOHN WEBSTER
0009
0010
0011
0012
0013
0014                          STORE = 105 / STORE
0015
0016                          /PAGE 0
0017
0018                          *0
0019
0020  000  0020    PTHADR,  0                 /INTRPT RETURN ADDR
0021  001  5026    INTRPT,  JMP   INTSRV      /INTRPT PNTR
0022
0023
0024                          /AUTOINDEX REGISTERS
0025                          *13
0026  013  0000    A13,     0                 /RESERVED FOR A/D...
0027  014  0000    A14,     0                 /BUFFER POINTER
0028  015  0000    A15,     0                 /RESERVED FOR DIFF...
0029  016  0000    A16,     0                 /SCORE POINTERS
0030  017  0000    DATAP,   0                 /DATA STORE POINTER
0031
0032
0033                          /INTERRUPT SERVICE ROUTINE
0034                          *26
0035  026  3106    INTSRV,  DCA   ACSAVE      /SAVE REGISTERS
0036  027  7004             RAL
0037  030  3107             DCA   LKSAVE
0038  031  6504             RCRA
0039  032  3110             DCA   CPASAV
0040  033  4056             JMS   GETACT      /GET ACTIVITY SCOPE
0041  034  1110             TAD   CRASPV      /RESTORE REGISTERS
0042  035  6535             LKERA
0043  036  6507             CAF
0044  037  1107             TAD   LKSAVE
0045  040  7010             RAR
0046  041  1106             TAD   ACSAVE
0047  042  6201             ION               /ENABLE INTRPT
0048  043  5400             JMP   I  PTHADR
0049
0050
0051                          /ACTIVITY SCOPE SET-UP
```

```
                        TAD     AWDRD   /SET UP PIE FOR A/D
                        WCPR
                        CLA IAC
                        JMS     A2D     /START WITH CH.1 (BIAS)
                        CIA
0057  7041    DCA       BIAS            /NEGATE AND SAVE
                        JMS     A2D     /THEN CH.0 (ACT)
                        TAD     BIAS    /FIND DIFFERENCE
                        DCA  I  A13     /PACK INTO BUFFER
                        TAD     A13
                        TAD     STKEND  /RESET BUFFER FNTP...
                        SZA CLA
                        JMP     .+3     /IF AT END (ENB)
                        TAD     STKBEG
                        DCA     A13
                        JMP  I  PEAR4D

                /ANALOG TO DIGITAL CONVERSION
         *66
A2D,                    WLT
                        WRITE1
                        CLA LL          /CHAN. SELECT
                        TAD     MCNT
                        DCA     MCNTR   /SET UP BACKUP CNTR
                        WRITE2
                        SKP2            /START CONVERSION
                        SKP             /DONE (EOC)?
                        JMP     DONE
                        ISZ     MCNTR   /NO, INCR. BACKUP
                        JMP     .-4
DONE,                   PEAR4           /YES
                        AND     X377    /MASK GARBAGE &
                        JMP  I  A2D     /EXIT

                /CONSTANTS AND VARIABLES
MAXEP,   0000   0                       /ACCUMULATES MAXIMAL EPOCH SCORE
LITE,    0000   0                       /HOLDS LITE LEVEL VALUE
ACSAVE,  0000   0                       /SAVES AC DURING INTRPT
LKSAVE,  0000   0                       /SAVES LINK DURING INTRPT
CRASAV,  0000   0                       /SAVES CRA DURING INTRPT
STKBEG,  0547   547                     /POINTS TO ACT SCORE BUFFER
ERROR,   0000   0                       /INITIAL CRA VALUE
AWDRD,   0201   201                     /-END OF ACT SCORE BUFFER
STKEND,  7221   7221
MCNT,    7766   7766                    /TIME DELAY FOR A/D
MCNTR,   0000   0                       /COUNTER FOR TIME DELAY
X377,    0377   377                     /USED TO MASK A/D CONV
M5,      7772   -6
BIAS,    0000   0                       /HOLDS TRANS. BIAS VALUE
CRBPTR,  4220   4220                    /INITIAL CRB VALUE
RATBEG,                                 /POINTS TO START OF RECORDER MEM.
```

0107	0020	MINCNT.	0	MINUTE COUNT
0108	0000	TCODE.	0	TIME CODE
0109	7775	M3.	-3	
0110	0000	GPPS.	0	COUNTER FOR TIME CODE
0111	0000	CCNTR.	0	.
0112	7773	M5.	-5	
0113	0000	TCNTR.	0	.
0114	0000	CODE1.	0	TIME CODE '0' OR '1'
0115	0000	TFLAG.	0	TIME CODE FLAG
0116	7742	M30.	-30	
0117	0000	MINDIV.	0	MINUTE DIVIDER
0118	0000	EPSUM.	0	ACCUMULATES EPOCH SUM
0119	0000	DFSUM.	0	ACCUMULATES DIFSCR SUMS
0120	7610	M120.	-120	
0121	0000	EPDIV.	0	EPOCH DIVIDER
0122	0000	SUM4.	0	ACCUMULATES SUM TO 4
0123	7774	M4.	-4	
0124	0000	CNT4.	0	COUNTS 4
0125	0177	X177.	177	MASK FOR DIFSCR
0126	7700	X7700.	7700	
0127	0000	DATLPD.	0	HOLDS DATA PRIOR TO STORE
0128	0600	COMETS.	COMET	POINTS TO TIME CODE RTN
0129	0400	DFSC.	DIFSCR	POINTS TO DIFSCR RTN
0130	0000	CRATMP.	0	TEMP CRA STORE
0131	1000	FLD1.	1000	CRA TO GET FIELD 1
0132	2001	MEMLOC.	2001	<- END OF FIELD
0133	7776	M2.	-2	
0134	7766	M10.	-10	
0135	7600	T200.	7600	
0136	4000	04000.	4000	
0137	0000	LATEST.	0	CRA TO WAIT
0138	0557	BUFLOC.	557	HOLDS MOST RECENT SUM4
0139	0000	BUFN.	0	POINTS TO DIFSCR BUFFER
0140	0000	MINUS.	0	BUFFER LOC
0141	0000	OFLOW.	0	
0142	0000	PPDCT.	0	
0143	0540	STORE.	STORES	
0144	0000	DIFOUT.	0	
0145	0000	BUFP.	0	
0146	7765	M11.	-11	
0147	7770	M8.	-8	
0148	7777	M1.	-1	
0149	0077	X77.	77	POINTS TO STORE RTN
0150				
0151				
0152				
0153				
0154				
0155				
0156				
0157				
0158				
0159				

```
/PAGE 1

         /START-UP
         *200
START,   CAF              /SET UP PIE
         TAD   AUOPD
         UCPA
         CLA   CLL
         TAD   BUOFD
         UCPB
         CLA   CLL
         TAD   DATBEG     /ZERO MEMORY
         DCA   DATHP
         DCA   DATURD
         STOPE
         SKP
         JMP   .-2
WAIT,    CLA   IAC        /WAIT FOR 'ON'
         JMS   A20
         TAD   M100       /IS SWITCH ON?
         SMA   CLA
         JMP   GO         /NO, WAIT
         FCPA
         TAD   04800
         UCPA
         JMP   WAIT
GO,      TAD   AUOP3      /YES, INIT & GO
         UCPA
         HOP
         CLA   CLL
         TAD   DATBEG
         DCA   DATAP
         TAD   FLBFLG
         DCA   MINCNT
         TAD   STKBEG
         DCA   A13
         TAD   STKBEG
         DCA   A14
MINIT,   TAD   MINCNT     /ENTER EACH MINUTE
         DCA   TCODE      /LOAD TIME CODE
         TAD   M4
         DCA   GRPS
         TAD   M4
         DCA   OCNTR
         TAD   M1
         DCA   TCNTR
         TAD   M1
         DCA   CODE1
         ISZ   TFLAG      /SET TIME CODE FLAG
         ISZ   MINCNT
         TAD   M30
         DCA   MINBIV
```

```
0215  3105         DCA   MINTOT
0216  3140  EPOCH. DCA   EPSUM      /ENTER EACH EPOCH
0217  3141         DCA   DFSUM
0218  1142         TAD   M120
0219  3143         DCA   EPDIV
0220  3144  FOUR.  DCA   SUM4       /ENTER EACH FOUR A/D'S
0221  1145         TAD   M4
0222  3146         DCA   CNT4
0223  1135         TAD   TFLAG
0224  7640         SZA CLA
0225  4552         JMS I CODETS
0226  6001         ION
0227  7300  EACH.  CLA CLL          /ENTER EACH A/D
0228  1013         TAD   A13
0229  7041         CIA
0230  1014         TAD   A14
0231  7440         SZA              /IS A/D BUFFER EMPTY?
0232  5315         JMP   NEW        /YES, ENTER WAIT STATE
0233  6504         PCRA
0234  7421         MQL
0235  7501         MQA
0236  1162         TAD   04000
0237  6505         WCRA
0238  7701         WCPM
0239  6505         WCPM
0240  7000         NOP
0241  7000         NOP
0242  5275         JMP   EACH       /NO, READ NEXT VALUE
0243  7300         CLA CLL
0244  1414         TAD I A14
0245  1144         TAD   SUM4       /AND SUM TO 4
0246  3144         DCA   SUM4
0247  1014         TAD   A14
0248  1114         TAD   STREND
0249  7640         SZA CLA
0250  5227         JMP   .+3
0251  1111         TAD   STKBEG
0252  3014         DCA   A14
0253  2146         ISZ   CNT4       /RESET BUFFER IF AT END
0254  5275         JMP   EACH
0255  1144         TAD   SUM4
0256  4553         JMS I DFSCR      /SUMMED 4 YET?
0257  7100         CLL              /NO
0258  1141         TAD   DFSUM      /YES, FIND DIFF. SCR.
0259  7430         SZL
0260  7240         STA
0261  3141         DCA   DFSUM      /ADD TO DIFSUM
0262  2143         ISZ   EPDIV
0263  5266         JMP   FOUR       /TRUNCATE IF TOO LARGE
0264  1141         TAD   DFSUM      /IS IT AN EPOCH YET?
0265  7110         CLL RAR          /NO
0266  7041         CIA              /YES, FIND MAXIMAL...
0267  1104         TAD   MAXVER     /EPOCH EACH MINUTE
```

```
0269   5253        JMP   .+4       /NO
0270   1141        TAD   DFSUM     /YES, REPLACE OLD
0271   7116        CLL RAR
0272   3104        DCA   MAXEP
0273   2155        ISZ   MINDIV    /IS IT A MINUTE YET?
0274   5262        JMP   EPOCH     /NO
0275   0002        TAD   .+5       /YES, READ LITE LEVEL
0276   1463        TAD   A2D       /FROM A/D, CH.2
0277   4066        JMS   DATLPD
0278   3151        DCA   .+5
0279   0001        TAD
0280   5257        JMP
0281   0002        2
0282   7000        MQP
0283   7000        MQP
0284   7000        MQP
0285   4571        STORE           /AND STORE IN RECORDER
0286   7402        HLT             /MEMORY
0287   1104        TAD   MAXEP     /NOW GET MAXIMAL EPOCH
0288   3151        DCA   DATLPD    /AND STORE IT IN NEXT
0289   4571        STORE           /MEMORY LOCATION
0290   7402        HLT
0291   5242        JMP   MINIT
```

```
        /PAGE 2

        /COMPUTE DIFFERENCE SCOPE
        *400
0323 7402   DIFSCR,  HLT
0324 3163            DCA   LATEST    /STORE MOST RECENT SUM
0325 1164            TAD   BUFLOC    /SET UP BUFF PNTRS
0326 3016            DCA   A16
0327 1174            TAD   M11
0330 3165            DCA   BUFN
0331 3340            DCA   MINLO     /CLEAR DP ADDER
0332 3341            DCA   MINHI
0333 3165
0334 3340
0335 3341
0336 7300   SUM,     CLA CLL
0337 1416            TAD I A16       /SUM LAST 11 SUM4'S
0338 7510            SPA
0339 5223            JMP   NEG
0340 1340            TAD   MINLO
0341 3340            DCA   MINLO
0342 7430            SZL
0343 7001            IAC
0344 1341            TAD   MINHI
0345 3341            DCA   MINHI
0346 5231            JMP   NEXT
0347 1340   NEG,     TAD   MINLO
0348 3340            DCA   MINLO
0349 7420            SNL
0350 7240            STA
0351 1341            TAD   MINHI
0352 3341            DCA   MINHI
0353 2165   NEXT,    ISZ   BUFN
0354 5210            JMP   SUM
0355 1174            TAD   M11
0356 3165            DCA   BUFN
0357 3342            DCA   PRDLO
0358 3343            DCA   PRDHI
0359 7000   LX10,    NOP
0360 7300            CLA CLL
0361 1365            TAD   BUFR+5
0362 7510            SPA
0363 5253            JMP   LNEG
0364 1342            TAD   PRDLO
0365 3342            DCA   PRDLO
0366 .730            SZL
0367 7001            IAC
0368 1343            TAD   PRDHI
0369 5343            DCA   PRDHI
0370 5261            JMP   LNXT
0371 1342   LNEG,    TAD   PRDLO
0372 3342            DCA   PRDLO
0373 7120            SNL
0374 7240            STA
0375 1343            TAD   PRDHI
```

/MUY CURR VAL
/BY 11

```
0377  2165  LNXT,   ISZ     BUFN
0378  5240          JMP     LX10
0379  7100          CLL
0380  1340          TAD     MINLO
0381  7041          CIA
0382  3340          DCA     MINLO
0383  7430          SZL
0384  7001          IAC
0385  1341          TAD     MINHI
0386  7041          CIA
0387  3341          DCA     MINHI
0388  7100          CLL
0389  1342          TAD     PPDLO
0390  1340          TAD     MINLO
0391  3342          DCA     PRDLO
0392  7430          SZL
0393  7001          IAC
0394  1343          TAD     PRDHI
0395  1341          TAD     MINHI
0396  3343          DCA     PRDHI
0397  1164          TAD     BUFLOC
0398  3016          DCA     A16
0399  1164          TAD     BUFLOC
0400  3015          DCA     A15
0401  1174          TAD     M11
0402  3165          TAD     BUFN
0403  1415  SHUFL,  TAD  I  A15
0404  3173          DCA     BUMP
0405  1163          TAD     LATEST
0406  3416          DCA  I  A16
0407  1173          TAD     BUMP
0408  3163          DCA     LATEST
0409  2165          ISZ     BUFN
0410  5313          JMP     SHUFL
0411  1342          TAD     PRDLO
0412  7510          SPA
0413  7041          CIA
0414  7002          BSW
0415  7004          RAL
0416  0147          AND     X177
0417  5600          JMP  I  DFSCR

0419                /
0420
0421          *540
0422  0000  MINLO.  0
0423  0000  MINHI.  0
0424  0000  PRDLO.  0
0425  0000  PRDHI.  0
0426  0000  SCNT.   0
0427  0000          0
0428  0000          0
0429  0000          0
```

BUFP.

0431	551	0000	0
0432	552	0000	0
0453	553	0000	0
0431	554	0000	0
0435	555	0000	0
0436	556	0000	0
0437	557	0000	0
0438	560	0000	0
0439	561	0000	0
0430	562	0000	0
0411	563	0000	0
0412	564	0000	0
0413	565	0000	0
0444	566	0000	0
0445	567	0000	0
0446	570	0000	0
0447	571	0000	0
0448	572	0000	0
0449			
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```
                    /PAGE 3

                    /GENERATE TIME CODE (OCTAL MINUTES)
                    *600
0490  600  7402  CODET,   HLT           /ENTER EACH 4 A/D'S IF TFLAG SET
0491  601  2133           ISZ   TCNTR   /TIME FOR ANOTHER DIGIT
0492  602  5225           JMP   TOUT    /NO
0493  603  1160           TAD   M18
0494  604  3133           DCA   TCNTR
0495  605  2131           ISZ   OCNTR   /YES, START OCTAL GROUP
0496  606  5215           JMP   FLASH   /NO, OUTPUT DIGIT
0497  607  1145           TAD   I14     /YES, SKIP DIGIT
0498  610  3151           DCA   OCNTP
0499  611  2150           ISZ   GRP5    /4 OCTAL GROUPS YET?
0500  612  7410           SKP
0501  613  3135           DCA   TFLAG   /YES, CLEAR TFLAG
0502  614  5225           JMP   TOUT
0503  615  6506  FLASH,   STLITE        /LITE ON
0504  616  1126           TAD   TCODE
0505  617  7104           CLL RAL
0506  620  3126           DCA   TCODE   /GET NEXT MSB
0507  621  7430           SZL
0508  622  1127           TAD   M4      /BINARY 1 OR 0?
0509  623  1176           TAD   M1      /1:HOLD LITE 5 UNITS
0510  624  3134           DCA   CODE1   /0:HOLD LITE 1 UNIT
0511  625  1134           TAD   CODE1
0512  626  7500           SMA           /HOLD LITE ON?
0513  627  6507           CLLITE
0514  630  7001           IAC           /NO, CLEAR IT
0515  631  3134           DCA   CODE1   /YES
0516  632  5600           JMP I CODET
0517
0518
0519                /STORE DATA
0520                *640
0521  640  7402  STORES,  HLT
0522  641  6504           PCRA          /SAVE CRA
0523  642  3154           DCA   CRATMP
0524  643  1124           TAD   FLDFLG  /WHICH FIELD?
0525  644  7650           SNA CLA
0526  645  5251           JMP   .+4
0527  646  1155           TAD   FLD1    /IF FLD 1 CHANGE FLDS
                          WCRA
0528  647  6505           CLA CLL
0529  650  7300           TAD   DATURD  /GET DATA
0530  651  1151           DCA I DATAP   /STORE IT
0531  652  3417           TAD   CRATMP  /RESTORE CRA
0532  653  1154           WCRA
0533  654  6505           CLA CLL
0534  655  7300           TAD   DATAP
0535  656  1017           TAD   MEMLIM  /IS MEMORY FULL?
0536  657  1155           SNA CLA
```

```
0539  662   2210        ISZ    STORES      /NO, RETURN +1
0540  663   5640        JMP  I STORES      /YES, WHICH FLD?
0541  664   1124        TAD    FLDFLG
0542  665   7440        SZA
0543  666   5640        JMP  I STORES      /FLD 1, RTRN & END
0544  667   2124        ISZ    FLDFLG      /FLD 0, SWITCH TO FLD 1
0545  670   7240        STA
0546  671   3017        DCA    DATAP       /RESET DATA PNTR TO TOP
0547  672   2240        ISZ    STORES
0548  673   5640        JMP  I STORES      /RTRN +1
0549
0550
0551
0552                    /RECORDER MEMORY
0553
0554                    /MAXIMAL EPOCH ACTIVITY SCORE AND
0555                    /LITE LEVEL FOR EACH MINUTE ARE
0556                    /STORED IN ALTERNATE MEMORY LOCS
0557                    /FROM LOC. 700 TO 5777 (FLD 0)
0558                    /AND 10000 TO 15777 (FLD 1)
0559
0560                    *700
0561
0562
0563                    $$$
```

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